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Robert Lee Taylor

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17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Probability, Applied Probability, Epidemiology, Algorithms, Finance, Genetics, Networks, Point Processes, Branching Processes, Symposium

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Symposium in Applied Probability was held as scheduled. Included in the sessions were probability problems inspired by physics, models in epidemiology, probability in the theory of algorithms, mathematical models in finance, mathematical genetics, point processes, self-similar processes, networks, and branching processes. A volume of selected proceedings, fully referred and edited, will be published.

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FINAL REPORT
ARMY OFFICE OF RESEARCH
GRANT #DAAL03-89-G-0039

February 5, 1990

Robert Lee Taylor
IMS Associate Program Secretary
for Probability and Its Applications
1987-1989

This final report describes the activities which are associated with the AOR Grant #DAAL03-89-G-0039 and the IMS Symposium on Applied Probability Sheffield, Sheffield, England, August 16-19, 1989. The first part of this report briefly summarizes the sequence of

1. obtaining requests for financial support,
2. determining awardees and amounts of stipends, and
3. disbursing of funds and obtaining expense statements.

Detailed documentation is provided in the attached appendices with reference to the total information in the IMS Business Office. A copy of the Program for the Symposium is enclosed and is included in the Appendices.

Applications for financial support in attending the IMS Symposium on Probability and Its Applications appeared in several professional journals (for example, see Appendix 1) along with the announcements for the Symposium. In addition, this information and application form were available upon request. In accordance with the terms of the grant, a travel grant committee was appointed by IMS President, R. Gnanadesikan, (see Appendix 2) to select the awardees. The Travel Grant Committee consisted of Lynne Billard, Program Secretary for IMS, Pat Jacobs, N. U. Prabhu, Co-chair, Program Committee for the Symposium, Secretary for IMS, and Robert Lee Taylor (Committee Chairman), IMS Associate Program Secretary for Probability and Its Applications.

The deadline for requesting financial support was June 1, 1989. Thirty-six applications for funding had been received by June 1, 1989. The twenty-one awards (5 from AOR Grant DAAL03-89-G-0039) which were recommended by the Committee (see Appendix 3) gave preference to invited speakers and young investigators. The amount of the awards reflected economical, advance-booking, air fare and some per diem expenses. Appendix 4 contains a representative copy of the letter of award which identified the source of the funding and the instruction for reporting expenses and acknowledging of the grant support.

The deadline for filing expense statements was September 15, 1989. In October, the travel grant committee reviewed the expenses and additional requests. The recommendations of October 31, 1989 (see Appendix 5) reflect the priorities of the grant, and final disbursement of grant funds was completed by November 16, 1989 (see Appendix 6 for details and representative letter of final disbursements).

The IMS Symposium on Applied Probability - Sheffield was very successful with approximately 150 participants. Appendices 7 and 8 contain additional details on the Symposium and the program. A large part of this success can be attributed to the ONR, NSF and AOR grant funds which were used in funding 10 of the invited speakers and in helping 9 young scientists attend and participate in the Symposium.

Copies to:

N. U. Prabhu
Department of Operations Research
338 Upson Hall
Cornell University
Ithaca, NY 14853

IMS President, Shanti Gupta
Department of Statistics
Math. Sciences Building
Purdue University
West Lafayette, IN 47907

IMS Treasurer, Jessica Utts
IMS Business Office
3401 Investment Boulevard
Suite 7
Hayward, CA 94545

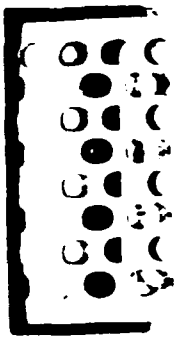
IMS Business Manager, Jose Gonzales
IMS Business Office
3401 Investment Boulevard
Suite 7
Hayward, CA 94545

APPENDIX 1

The IMS Bulletin
Vol.18, No.1, 1989, 58-62.

Sheffield, England

16-19 August 1989



The 211th meeting of the Institute of Mathematical Statistics (IMS) will be held at the University of Sheffield, Sheffield, England, U.K., from 16-19 August 1989. This will be a special International Symposium on Applied Probability cosponsored by the University of Sheffield. Deadline for receipt of abstracts in the *Bulletin* Editorial Office in Montréal is 14 April 1989.

Program Co-Chair: Chris Cannings, Department of Probability & Statistics, University of Sheffield, Sheffield S3 7RH, England, UK; ST1CWA@PRIMEA.SHEFFIELD.AC.UK.

Program Co-Chair: N. U. Prabhu, Department of Operations Research, Cornell University, 338 Upson Hall, Ithaca, New York 14853, USA; (607) 255-9132.

IMS PROGRAM COMMITTEE

Karl DIETZ, *Universität Tübingen,*
Peter J. DONNELLY, *Queen Mary College, London,*
Peter JAGERS, *Chalmers Tekniska Hogskola, Göteborg,*
Alan F. KARR, *Johns Hopkins University, Baltimore, Maryland,*
Francis P. KELLY, *University of Cambridge,*
Harry KESTEN, *Cornell University, Ithaca, New York*
S. SHREVE, *Carnegie Mellon University, Pittsburgh,*
J. Michael STEELE, *Princeton University*
Murad S. TAQQU, *Boston University, Boston,*
Robert Lee TAYLOR, *University of Georgia, Athens.*

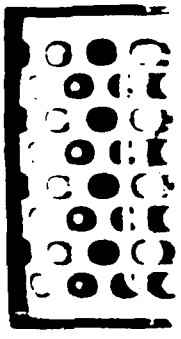
The major **Invited Speakers** include: Richard T. DURRETT, *Cornell University, Ithaca, New York,* David G. KENDALL, *University of Cambridge,* and Chris C. HEYDE, *Australian National University, Canberra.* **Special Sessions** include:

PROBABILITY PROBLEMS INSPIRED BY PHYSICS

Organizer: Harry KESTEN, *Cornell University, Ithaca, New York.*

Invited Speakers:

Detlef DURR, *Universität Bielefeld*
Claude KIPNIS, *Université de Paris VII*
Erwin BOLTHAUSEN, *Technische Universität Berlin.*



MODELS IN EPIDEMIOLOGY

Organizer: Karl DIETZ, *Universität Tübingen.*

Invited Speakers:

Norman T.J. BAILEY, *WHO – Geneva*
Niels G. BECKER, *La Trobe University, Bundoora, Victoria*
Henry E. DANIELS, *University of Cambridge.*

MATHEMATICAL MODELS IN FINANCE

Organizer: Steven E. SHREVE, *Carnegie Mellon University, Pittsburgh.*

Invited Speakers:

M.H.A. DAVIS, *London*

J. Darrell DUFFIE, *Stanford University*

David C. HEATH, *Cornell University, Ithaca, New York.*

QUEUEING NETWORKS

Organizer: Francis P. KELLY, *University of Cambridge.*

Invited Speaker:

Peter WHITTLE, *University of Cambridge.*

PROBABILITY IN THE THEORY OF ALGORITHMS

Organizer: J. Michael STEELE, *Princeton University.*

Invited Speakers:

David ALDOUS, *University of California, Berkeley*

Luc DEVROYE, *McGill University, Montréal*

J. Michael STEELE, *Princeton University.*

MATHEMATICAL GENETICS

Organizer: Peter J. DONNELLY, *Queen Mary College, London.*

Invited Speakers:

Simon TAVARÉ, *University of Utah*

Geoffrey WATTERSON, *Monash University, Clayton, Victoria.*

SELF-SIMILAR PROCESSES

Organizer: Murad S. TAQQU, *Boston University.*

Invited Speakers:

Alex SAMAROV, *University of Lowell and MIT*

George O'BRIEN, *York University, North York, Ontario*

Herold DEHLING, *University of Groningen.*

BRANCHING PROCESSES

Organizer: Peter JAGERS, *Chalmers University of Technology, Göteborg.*

Invited Speakers:

Volodya VATUTIN, *Moscow*

Brigette CHAUVIN, *Paris.*

Transportation: If you come by air, you will travel to London – Heathrow (LHR) or Gatwick (LGW) or to Manchester (MAN). Although Manchester is closer to Sheffield than London is, it is probably not worthwhile taking an internal flight from London to Manchester. From London Heathrow, travel by underground train direct to King's Cross St. Pancras station and then by British Rail inter-city train from St. Pancras to Sheffield. The total journey time is about four hours and the "saver" return fare is about £30. [Exchange rate as of 31 December 1988: £1.00 = US$1.81.] From London Gatwick, British Rail runs trains to London Victoria and Luton stations. From Victoria, take the underground (Victoria Line) to King's Cross St. Pancras and then proceed as above; alternatively, at Luton the inter-city train from St. Pancras to Sheffield is available. In either case, the journey time and fare are about the same as from Heathrow. From Manchester airport, take a bus direct to Sheffield, or, if there is not one convenient, take a bus into Manchester Piccadilly station from which there is a frequent rail service to Sheffield. Journey time is about two hours. Internally, Sheffield is well linked by rail to all major centers of population and to the East and South coast ports. For travelers by road, Sheffield is about 160 miles from London and about 5 miles from the M1 motorway.

Accommodation: Accommodation is provided in single study bedrooms, although a limited number of double rooms are available, in Earnshaw Hall, a modern hall of residence of the University about two miles west of the city centre. The conference sessions are in the University itself, half way between Earnshaw Hall and the city centre. Transport will be provided free of charge to and from the conference sessions for those who require it. Breakfast is included in the cost of accommodation. For participants requiring hotel accommodation, details of two hotels are given on the Registration Form (page 62). These hotels are close to Earnshaw Hall and the University.

Special event: On Friday evening, 18 August 1989, there will be a special banquet in honour of Joseph M. Gani. This must be booked and paid for separately, and there will be no other meals provided on this evening.

Other meals: Light lunches will be provided, for those who have ordered them, in University House, close to the conference sessions. Evening meals will be provided in Earnshaw Hall. Both lunches and evening meals must be booked in advance if required. As an alternative, there are various restaurants and pubs serving food in the vicinity of the University.

Sheffield and environment: Sheffield is a city of half a million inhabitants, historically based on the steel and cutlery industries. Sheffield is in South Yorkshire, about 70 miles north-north-east of Birmingham and 20 miles south-west of Doncaster. With a population of half-a-million, Sheffield has been the centre of the English cutlery industry from the early 18th century. Sheffield plate (a process invented by Thomas Boulsover, 1704-1788) is produced by fusing copper with silver, giving a beautiful surface like that of standard silver. The development of steel in the nineteenth century led to the rapid expansion of Sheffield, but the manufacture of cutlery goes back many centuries, founded on the swift-flowing streams which drain the nearby Pennines. Today, the city has been much rebuilt, partly due to bomb damage in the Second World War, and a clean air policy initiated in the 1960's has transformed the atmosphere. Much of the heavy industry has gone, but is well commemorated in the city's Kelham Island Museum. Among the largest employers nowadays are educational institutions and the health service. Recently, the Midland Bank and the government's Training Commission have set up their headquarters in Sheffield. Yet the many opulent Victorian and Edwardian residences in the western suburbs bear witness to an earlier age of industrial affluence. The wild Pennine moorlands encroach within the city boundary and provide contrasting recreational facilities.

The moorlands form a frame to the Peak District of Derbyshire. In the interior, limestone dominates and gives rise to spectacular formations, both above and below ground: towering crags, steep sided gorges, networks of subterranean passages. The Peak District is also the setting for two of Britain's finest country houses, both open to the public: Chatsworth, home of the Duke and Duchess of Devonshire, a grand Baroque mansion set in magnificent parkland, and Haddon Hall, a mediaeval manor house carefully restored in the present century by the Dukes of Rutland and preserving a delightfully intimate and authentic atmosphere.

In other directions, Sheffield has good road access to many places of architectural, historical and literary interest: for instance, the Elizabethan masterpiece of Hardwick Hall, the ancient city of York with its imposing Minster, and the village of Haworth, home of the Brontë sisters.

In common with the rest of the United Kingdom, Sheffield has an interestingly unpredictable climate, and so it might be wise to bring an umbrella or raincoat. Daytime temperatures in August can reach the thirties Celsius, though a more typical value would be around 20 degrees.

application for financial support

Symposium on Applied Probability

16-19 August 1989: University of Sheffield, England

Funding support for distinguished speakers and other attendees (in particular, young investigators) has been requested from several agencies. Some external funding is expected and will be awarded in the form of stipends only. Funding decisions will be made by an IMS committee. Young investigators may wish to include a brief supporting letter from a senior scientist (or dissertation adviser), which documents the benefits for the applicant in attending the Symposium. Everyone should seek the most economical travel fares to optimize the dispersion of support. Applicants are encouraged to have their applications for funding completed and sent to the IMS Business Office by 1 June 1989. Decisions on support will be announced soon after the 1 June 1989 deadline.

Name _____ Affiliation _____

Address _____

City _____ State/Province _____ Zip/Postal Code _____

Country _____

Invited presentation _____ Contributed presentation _____

Chair of session _____ Young investigator _____ Date of degree _____

Memberships: IMS _____ Others (specify) _____

Estimated costs of travel (specify destinations) _____

_____

Estimated other costs _____

_____

Send this application form to :

The IMS Business Office, Request for Funding – Applied Probability Symposium,

3401 Investment Boulevard, Suite 7, Hayward, CA 94545, USA.

APPENDIX 2

INSTITUTE OF MATHEMATICAL STATISTICS

Business Office • 3401 Investment Boulevard #7
Hayward, California 94545 (USA) • (415) 783-8141

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University of California, Davis
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Jose L. Gonzalez

December 13, 1988

To: Professors L. Billard
P. A. Jacobs
N. U. Prabhu
R. L. Taylor ✓

At the IMS Presidents Committee meeting last Friday, the proposal for funding travel to the Sheffield Symposium was signed by Jessica Utts and myself and mailed to Prabhu.

Assuming that the funding is approved, it was felt that I should appoint a screening committee for making the decisions on funding. This is to request the four of you to serve on such a committee. Three of you have responsibilities for the program and I cannot see how you can refuse, and I have talked to the fourth (Patricia Jacobs) and got her agreement to serve – so I shall assume that this committee is in place!

Thanks.

Sincerely,

Ram

R. Gnanadesikan
Bellcore
445 South Street
Room MRE 2Q-386
Box 1910
Morristown, NJ 07960-1910

Copy to
B. Efron
J. Gonzalez
S. S. Gupta
P. Purdue
J. Utts

APPENDIX 3

The University of Georgia

Franklin College of Arts and Sciences
Department of Statistics

June 13, 1989

MEMORANDUM

TO: Jessica M. Utts
IMS Treasurer

Jose L. Gonzalez
IMS Business Manager

FROM: Travel Grant Committee
R. L. Taylor, Chair *R L Taylor*

The Travel Grant Committee consists of Lynne Billard, Program Secretary for IMS, N. U. Prabhu, Co-Chair of the Symposium Program Committee, Robert L. Taylor, IMS Associate Program Secretary for Probability and its Applications, and Pat Jacobs. After careful consideration of the applications for funding, the Committee recommends that the following stipends be awarded.

from the NSF Grant DMS-8906957 to

	Total Award	Initial Amount to be Paid in June
Adler	$ 1,000	$ 600
Aldous	1,070	700
Athreya	1,100	700
Basawa	1,000	600
Bunge	830	500
(Total	$ 5,000)	

from the ONR Grant N00014-88-J-1069 to

Bunge	$ 165	$ 165
Chaganty	994	600
Duffie	1,149	750
Durrett	800	500
Godbole	1,000	600
Hajek	1,100	700
Hansen	150	150
Harrison	900	600
Heath	1,100	700
Kolassa	700	500
Nguyen	740	500
Patterson	1,000	600
Phelen	202	202
(Total	$10,000)	

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from the AOR Grant DAAL03-89-G-0039

Phelen	$ 779	$ 400
Samarov	1,100	700
Shreve	1,100	700
Steele	921	600
Taggu	1,100	700
(Total	$ 5,000)	

At this time, no stipends are recommended for

Archie	Griffiths
Basu	Hochberg
Becker	Kipnis
Bolthausen	Merzbach
Dattatraya	O'Brien
Davis	Parikh
Durr	Prabhu
	Weissman

cc: R. Gnanadesikan
N. U. Prabhu

APPENDIX 4

INSTITUTE OF MATHEMATICAL STATISTICS

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Hayward, California 94545 (USA) • (415) 783-8141

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David R. Cox
Thomas S. Ferguson
Wayne A. Fuller
Marjorie G. Hahn
Harry Kesten
Sidney I. Resnick
Jayaram Sethuraman
Adrian F. M. Smith
J. Michael Steele
William Strawderman

3 July 1989

Professor Andre Adler
Department of Mathematics
Illinois Institute of Technology
Chicago IL 60616

Dear Professor Adler:

The IMS Travel Grant Committee for the Symposium on Applied Probability (Sheffield, 16-19 August 1989) consisted of the IMS Program Secretary, IMS Associate Program Secretary for Probability and its Applications, Co-Chair of the Program Committee for the Symposium, and one other member.

The Committee has recommended that you be awarded a stipend of $1000 for travel and expenses relating to your participation in the Symposium. The funding is available from a National Science Foundation Grant, Number DMS-8906957. Acknowledgement of this financial support is required on every scientific and technical document prepared with the support of this Grant. Any air transportation to, from, between, or within, a country other than the United States of persons or property, the expense of which will be assisted by NSF funding, must be performed on a US-flag carrier if service provided by such a carrier is available.

Your help in adhering to the terms of the Grant is greatly appreciated. Please send materials related to this Grant to:

IMS Travel Grant Committee
c/o IMS Business Office
3401 Investment Boulevard #7
Hayward CA 94545 (USA)

If you will not be able to attend the Symposium, then please return the award check to the IMS Business Office as soon as possible. If your expenses are less than your award, then the balance is to be returned to the IMS Business Office by check payable to the Institute of Mathematical Statistics. Any unused funds may be redistributed to participants who were not originally funded and/or to participants whose expenses exceeded

their award.

A brief report of your expenses in attending the Symposium is required by the funding agencies and should include your social security number (if applicable), a copy of you airline ticket(s), and a copy of the registration receipt. Please send this report to the IMS Business Office by 15 September 1989. A check for $600 is included with this letter, and the remaining part of the total stipend will be paid upon receipt of your expense report.

Congratulations on your award. The Institute is pleased to assist in your participation at the Symposium.

Sincerely yours,

Jose L Gonzalez
IMS Business Manager

encl

cc IMS Travel Grant Committee
Symposium on Applied Probability
(Sheffield, 16-19 August 1989)

APPENDIX 5

The University of Georgia

Franklin College of Arts and Sciences
Department of Statistics

October 31, 1989

MEMORANDUM

TO: Jessica M. Utts and Jose L. Gonzalez
IMS Treasurer
Division of Statistics
University of California
469 Kerr Hall
Davis, California 95616

Business Manager
IMS Business Office
3401 Investment Boulevard
Suite 7
Hayward, California 94545

FROM: Travel Grant Committee, Sheffield
R. L. Taylor, Chair Bob Taylor

The Travel Grant Committee for the IMS Symposium at Sheffield, 1989 consisted of Lynne Billard, Program Secretary for IMS, N. U. Prabhu, Co-chair of the Symposium Committee, Robert L. Taylor, IMS Associate Program Secretary for Probability and its Applications, and Pat Jacobs. After careful consideration of the expenses by the applicants, the committee recommends that the final disbursement of funds be awarded:

	Initial Amount Requested	Expenses	June's NSF Award	Recommended Additional NSF Award	AOR Award
Alder	$ 1,100.00	$ 1,056.60	$ 600.00	$ 400.00	$ 56.60
Aldous	1,070.00	1,060.00	700.00	360.00	--
Athreya	1,100.00	1,341.32	700.00	445.00	100.00
Basawa	1,157.00	1,136.00	600.00	400.00	136.00
Bunge	995.00	1,130.70	500.00	295.00	--
			$3,100.00	$1,900.00	

(From NSF Grant DMS-8906957 Total $5,000.00)

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	Initial Amount Requested	Expenses	June's ONR Award	Recommended Additional NSF Award	AOR Award
Bunge	As above	As above	$ 165.00	--	$ 170.70
Chaganty	$ 994.00	$ 1,239.96	600.00	$ 394.00	197.46
Duffie	1,149.00	1,405.23	750.00	399.00	251.00
Durrett	800.00	800.00	500.00	300.00	--
Godbole	1,500.00	1,538.71	600.00	435.20	150.34
Hajek	1,100.00	1,064.80	700.00	364.80	--
Hansen	150.00	150.00	150.00	--	--
Harrison	900.00	1,551.57	600.00	300.00	500.00
Heath	1,100.00	1,349.01	700.00	400.00	199.01
Kolassa	700.00	753.86	500.00	200.00	53.86
Nguyen	740.00	983.51	500.00	240.00	243.51
Patterson	1,100.00	1,024.80	600.00	400.00	24.80
Phelen	981.00	1,004.75	202.00	--	--
			$6,567.00	$3,433.00	

(From ONR Grant N00014-88-J-1009 Total $10,000)

	Initial Amount Requested	Expenses	June's AOR Award	Recommended Additional AOR
Phelen	As above	As above	$ 400.00	$ 402.75
Shreve	$ 1,100.00	$1,242.97	700.00	492.97
Steele	921.00	921.00	600.00	321.00
			$1,700.00	$3,300.00

(From AOR Grant DAAL03-89-G-0039 Total $5,000)

This should complete our duties. Please let me know if you encounter any problem with the final disbursement of the grant funds.

cc: R. Gnanadesikan
S. Gupta
L. Billard
P. Jacobs
N. U. Prabhu

APPENDIX 6

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Adrian F. M. Smith
William Strawderman

16 November 1989

Professor Robert Taylor
Department of Statistics
204 Statistics Building
University of Georgia
Athens GA 30602

Dear Professor Taylor:

We have sent additional stipend checks to the participants in the International Symposium on Applied Probability (Sheffield, 16-19 August 1989) listed in your memo of 31 October 1989. Copies of letters accompanying the checks are enclosed.

We need to have a copy of the final report for the Symposium prior to requesting reimbursement for our final expenses from NSF, ONR, and ARO. We look forward to receiving a copy of your final report in the very near future.

Thank you very much for your cooperation in this matter.

Sincerely yours,

Jessica Utts

Jessica Utts
IMS Treasurer

encl

INSTITUTE OF MATHEMATICAL STATISTICS

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William Strawderman

16 November 1989

Professor Andre Adler
Department of Mathematics
Illinois Institute of Technology
Chicago IL 60616

Dear Professor Adler:

The IMS Travel Grant Committee for the International Symposium on Applied Probability (Sheffield, 16-19 August 1989) consisted of the IMS Program Secretary, IMS Associate Program Secretary for Probability and its Applications, Co-Chair of the Program Committee for the Symposium, and one other member.

The Committee has examined your expense report and has recommended that you be awarded an additional stipend of $456.60 for travel and expenses relating to your participation in the Symposium. This funding is available from a National Science F undation Grant, Number DMS-8906957, and Army Research Office Grant, Number DAAL03-89-G-0039.

Congratulations on your award. The Institute is pleased to have assisted in your participation at the Symposium.

Sincerely yours,

Jose L Gonzalez
IMS Business Manager

encl

cc IMS Travel Grant Committee
Symposium on Applied Probability
(Sheffield, 16-19 August 1989)

APPENDIX 7

Preprint from IMS Bulletin

INTERNATIONAL SYMPOSIUM ON APPLIED PROBABILITY SHEFFIELD, ENGLAND, U.K., 16-19 AUGUST 1989

The 211th IMS meeting was a special Symposium on Applied Probability which was cosponsored by the University of Sheffield. The purpose of the Symposium was to focus special attention on some of the more prominent directions in applied probability. The Symposium was supported by British Telecom plc, The Royal Society, Science and Engineering Research Council, US (London) Army Research Office, (London) Office of Naval Research Grant N00014-89-J-9042, US Army Research Office Grant DAAL03-89-0099, US National Science Foundation Grant DMS-8906957 and US Office of Naval Research Grant N00014-89-J-1830. These grant funds helped defray expenses for the participants, especially young scientists and invited speakers.

There were approximately 150 participants. Roughly, one-half were from the United Kingdom, over one-fourth from North America, approximately one- fifth from Europe and some participants were from the Far East and Australia. There was a noticeable proportion (10 to 15%) of research students, mostly from the United Kingdom.

The major presentations were by Richard T. Durrett, "Interacting Particle Systems Inspired by Biology", Chris C. Heyde, "On the Modelling and Identification of Random Processes and Fields Subject to Possible Long-Range Dependence", and David G. Kendall, "The Metric Structure of Euclidean Shape Spaces: A New Environment for Statistics".

We are most grateful to the co-program chairs Chris Cannings and N. U. Prabhu, the entire program committee and the Department of Probability & Statistics at the University of Sheffield for an excellent Symposium. The local organizing committee of R. M. Loynes (chair), C. W. Anderson, J. D. Biggins, and D. R. Grey provided excellent arrangements and social activities. Symposium participants were hosted at the Town Hall by The Lord Mayor of the City of Sheffield one evening, provided with a reception by the University of Sheffield on another evening and attended a banquet in honor of Professor J. Gani.

Publication of selected proceedings of the Symposium are planned in the IMS LECTURE NOTES with I. V. Basawa and R. L. Taylor, University of Georgia, as editors.

R. L. Taylor, IMS Associate Program Secretary for Probability and its Applications, Department of Statistics, University of Georgia, Athens GA 30602.

APPENDIX 8

UNIVERSITY OF SHEFFIELD/INSTITUTE OF MATHEMATICAL STATISTICS

SYMPOSIUM ON APPLIED PROBABILITY

SHEFFIELD, 16-19 AUGUST, 1989

FINAL PROGRAMME

The main symposium sessions will take place in Arts Tower Lecture Theatre 4. Parallel contributed paper sessions will take place in Lecture Theatres 4, 6 and 9, as indicated in the programme. All lecture theatres are located on the lower ground floor of the Arts Tower.

The symposium acknowledges with gratitude the support of the following:-

British Telecom plc
The Royal Society
The Science and Engineering Research Council
US (London) Army Research Office
US (London) Office of Naval Research } Grant N00014-89-J-9042
US Army Research Office, Grant DAAL03-89-0039
US National Science Foundation, Grant DMS-8906957
US Office of Naval Research, Grant N00014-89-J-1830

SYMPOSIUM ON APPLIED PROBABILITY

PROGRAMME

WEDNESDAY, 16 AUGUST

8.45-9.15	**OPENING** Chairman, R.M. LOYNES V. BARNETT, Pro-Vice-Chancellor, University of Sheffield IMS Representative	
9.15-11.00	**INVITED PAPERS I: PROBABILITY PROBLEMS INSPIRED BY PHYSICS.** Chairman, B. NGUYEN	
9.15	~~On the diffusion of particle in simple fluids~~	~~K. DURR~~
9.50	Title ?	C. KIPNIS
10.25	On the diffusive behaviour of directed polymers in random environments	E. BOLTHAUSEN
11.20-12.20	**SPECIAL INVITED PAPER I.** Chairman, U. PRAHBU Interacting particle systems inspired by Biology	R. DURRETT
1.45-3.30	**INVITED PAPERS II: MODELS IN EPIDEMIOLOGY** Chairman, K. DIETZ	
1.45	Poisson approximations for some epidemic models	A.D. BARBOUR
2.20	Analysis of infectious disease data from a sample of households	N.G. BECKER
2.55	A look at perturbation approximations to epidemics	H.E. DANIELS
3.55-4.30	**INVITED PAPERS II(i) PROBABILITY IN THE THEORY OF ALGORITHMS.** Chairman, J.M. STEELE	
3.55	On the shape of random trees	L. DEVROYE

4.30-5.45	**CONTRIBUTED PAPERS I.** (Lecture Theatre 4) Chairman, I.V. BASAWA	
4.30	Multi-level branching as a measure-valued process	K. HOCHBERG D.A. DAWSON
4.45	Tests for the characteristic exponent in a class of stable distributions	H.I. PEREIRA
5.00	Strong moderate deviation theories for m-dependent random variables. Preliminary Report	N.R. CHAGANTY
5.15	Strong laws of large numbers for weighted sums of random elements in normed linear spaces	A. ADLER A. ROSALSKY R.L. TAYLOR
5.30	Strong convergence for sums of randomly weighted rowwise exchangeable random elements	R.F. PATTERSON R.L. TAYLOR H. INQUE
4.30-5.30	**CONTRIBUTED PAPERS II** (Lecture Theatre 6) Chairman, D. MOLLISON	
4.30	Estimating the extreme value index	L. de HAAN
4.45	The distribution of certain record statistics from a random number of observations	J.A. BUNGE H.N. NAGARAJA
5.00	Some examples of Poisson approximation by the Stein-Chen method and coupling	L.K. HOLST
5.15	Degenerate and Poisson convergence criteria for success runs	A.P. GODBOLE
4.30-5.30	**CONTRIBUTED PAPERS III** (Lecture Theatre 9) Chairman, D.R. GREY	
4.30	Two queues with a single server	S.E. HITCHCOCK
4.45	A fluctuation limit for scaled age distributions and weighted Sobolev spaces	A. BOSE
5.00	A linear random growth model	M.P. QUINE
5.15	First passage times in nonlinear renewal theory	A. GUT

THURSDAY, 17 AUGUST

8.45-10.30	**INVITED PAPERS III: MATHEMATICAL MODELS IN FINANCE.** Chairman, S.E. SHREVE	
8.45	More on portfolio selection with transaction costs	M.H.A. DAVIS
9.20	Continuous time recursive utility	D. DUFFIE
9.55	Arbitrage and martingales	D.C. HEATH
11.00-12.10	**INVITED PAPERS IV: PROBABILITY IN THE THEORY OF ALGORITHMS.** Chairman, J.M. STEELE	
11.00	Computer science applications of random walks on graphs	D.L. ALDOUS
11.35	Combinatorial optimization and probability theory	J.M. STEELE
2.00-3.45	**INVITED PAPERS V: MATHEMATICAL GENETICS** Chairman, P.J. DONNELLY	
2.00	The biology of random permutations	S. TAVARÉ
2.35	Weak convergence of ancestral processes in population genetics	P.J. DONNELLY
3.10	The two locus infinitely-many-alleles model and the ancestral tree of a sample of genes	R.C. GRIFFITHS S.N. ETHIER
4.15-6.00	**INVITED PAPERS VI: POINT PROCESSES: APPLICATIONS AND INFERENCE.** Chairman, A.P. KARR	
4.15	Modelling and inference for rainfall fields	M.J. PHELAN
4.50	Viewpoints on evolving random fields	P.E. GREENWOOD
5.25	Partial observations, partial model specification, and the structure of likelihood for point processes	E. ARJAS P. HAARA

FRIDAY, 18 AUGUST

9.20-10.30	**INVITED PAPER VII: SELF-SIMILAR PROCESSES** Chairman, G. O'BRIEN	
9.20	Stationary self-similar extremal processes	G. O'BRIEN
9.55	U-statistic for long-range dependent observations	H. DEHLING M. S. TAQQU

11.00-12.45	**INVITED PAPERS VIII: NETWORKS** Chairman, F.P. KELLY	
11.00	Networks showing excitation and a multi-model equilibrium distribution	P. WHITTLE
11.35	Deflection routing in a hypercube network	B. HAJEK
12.10	Brownian model of stochastic networks	M. HARRISON
2.15-3.15	**SPECIAL INVITED PAPER II** Chairman, R.M. LOYNES	
	On the modelling and identification of random processes and fields subject to possible long-range dependence	C.C. HEYDE
3.45-5.30	**CONTRIBUTED PAPERS IV:** (Lecture Theatre 4) Chairman, R.M. LOYNES	
3.45	An urn model for the probability of a boy	F. DALY
4.00	Application of the Stein-Chen method to materials strength problems	R.L. SMITH S. LEIGH
4.15	Saddlepoint approximations for intractable cumulant generating functions	J.E. KOLASSA
4.30	On the distribution of the sum of two discrete uniform random variables with applications	S.A. PATIL
4.45	On a study of certain power mixtures	W.J. HUANG L.S. CHEN
5.00	Resampling methods for dependent data	I.V. BASAWA
5.15	~~On the iterated logarithm law for the maximum in Gaussian processes~~	~~S.Y. TANG~~
3.45-5.30	**CONTRIBUTED PAPERS V:** (Lecture Theatre 6) Chairman, A. ADLER	
3.45	Products of infinite-dimensional random matrices related to particle systems	R.W.R. DARLING
4.00	Annihilating and coalescing particle systems: models of diffusion-limited reactions	D. BALDING
4.15	An urn model and the coalescent in neutral infinite-alleles genetic processes	D. BRANSON
4.30	A functional central limit theorem for Ewens sampling formula	J.C. HANSEN

4.45	Testing for inheritance of disease	J.R. GREEN
5.00	Tests for gene conversion	S. SAWYER
5.15	The structure of epidemic models	D. MOLLISON
3.45-5.30	**CONTRIBUTED PAPERS VI:** (Lecture Theatre 9) Chairman, J. HAIGH	
3.45	Martingale convergence in branching random walks	J.D. BIGGINS
4.00	Patterns of evolutionarily stable strategies	C. CANNINGS G.T. VICKERS
4.15	Extinction probabilities of branching processes in random environments	D.R. GREY L. ZHUNWEI
4.30	The calibration problem as an ill-posed inverse problem	C. HAGWOOD
4.45	Computer Algebra, Brownian motion, and the statistics of shape	W.S. KENDALL
5.00	U-statistics and the double stable integral	J. MINHEER
5.15	Image reconstruction - a new class of priors	R.G. MIDDLETON

SATURDAY, 19 AUGUST

9.00-10.45	**INVITED PAPERS VIII: BRANCHING PROCESSES** Chairman, P. JAGERS	
9.00	Building conditioned trees	B. CHAUVIN
9.35	Multitype branching processes in random environments, Osledec's Ergodic trheorem and Lyapunov exponents	K.P. ATHREYA
10.10	When did Joe's great....grandfather live? Or: On the timescale of evolution	P. JAGERS
11.15-12.15	**SPECIAL INVITED PAPER VII:** Chairman, C. CANNINGS	
	The metric structure of Euclidean shape spaces: a new environment for statistics	D.G. KENDALL

SYMPOSIUM ON APPLIED PROBABILITY

Date: August 16-19. 1989

Location: University of Sheffield

Lectures were held in the Arts Tower and participants were housed at Earnshaw Hall of Residence.

Organizers:

The Conference was jointly organized by the Institute of Mathematical Statistics and the Department of Probability & Statistics, University of Sheffield.

Sponsors: (in alphabetical order)

British Telecom plc	
The Royal Society	
Science and Engineering Research Council	
US (London) Army Research Office	Grant N00014-89-J-9042 US
(London) Office of Naval Research	
US Army Research Office	Grant DAAL03-89-0099
US National Science Foundtion	Grant DMS-8906957
US Office of Naval Research	Grant N00014-89-J-1830

Participants.

There were approximately 150 participants; a not quite accurate list of participants is enclosed, since people came who weren't expected and others who were expected didn't arrive as far as we know. It is, however, almost correct. Of the 150, very roughly, one half were from the United Kingdom, one quarter from North America and one quarter from Europe. There was also a noticeable proportion, probably between 10 and 15%, of research students, mostly from the United Kingdom.

Programme.

The programme is attached, as is an incomplete list of abstracts for the various talks.

Comments on programme.

It would be invidious to single out one or two speakers as particularly interesting and in fact the most obvious feature of the symposium was the very wide diversity of subject areas covered. The first stages in any application are invariably simple, but what is remarkable is how far on from the simple beginnings most of the areas seem to have gone. As an example of this one may quote queueing theory which from the early beginnings of single server queues in the 1950's have gone on to allow networks of queues of very general kinds, either modelled directly or by approximations as in heavy traffic and Brownian motion theory approaches. One the obvious features in this area, as in many others, is the effect of computing power. It is now possible to solve equations numerically or to carry out substantial simulations in order to get understanding of systems which could not otherwise be handled,

Publications

There will be volume of selected proceedings, fully refereed and edited.

Social Activities

The Lord Mayor of the City of Sheffield provided the reception at the Town Hall on the evening of Wednesday, 16 August. There was a banquet for participants on Friday, 18, which was preceded by a reception provided by the University of Sheffield.

Programme Committee Co-Chairman:

C. Canningss and N.U. Prabhu

Local Organising Committee:

C.W. Anderson, J.D. Biggins, D.R. Grey, R.M. Loynes (Chairman)

Other Matters:

The conference was partly in honour of Professor J. Gani and the banquet was specifically in his honour. He was Professor of Statistics in the University of Sheffield from 1965-74 and built up the general Applied Probability and Advances in Applied Probability.

The Symposium was apparently thought of as extremely successful. It is not easy to be sure of the long term effects but at least 20% of the participants went out of their way to approach me to tell me how well they thought it had gone and how interesting and useful it was.

R.M. Loynes

30 August 1989

Symposium on Applied Probability
IMS/Sheffield August 1989

Abstracts

211-1. **COMPUTER SCIENCE APPLICATIONS OF RANDOM WALKS ON GRAPHS**

David J. ALDOUS, *University of California, Berkeley.*

This is a survey talk on topics such as: approximate counting/simulation of large combinatorial sets; generating random spanning trees in graphs; existence of universal traversal sequences; and applications of covering time bounds. [Received: 16 November 1988.]

211-2. **PRODUCTS OF INFINITE-DIMENSIONAL RANDOM MATRICES RELATED TO PARTICLE SYSTEMS**

R.W.R. DARLING, *University of South Florida, Tampa.*

Let $A_1, A_2, \ldots$ be independent and identically distributed random matrices whose rows and columns are indexed by a countably infinite Abelian group (usually Z^d), whose entries are 0 or 1, and whose columns have an almost surely finite sum. It is also assumed that A_1 and A_1^{**} have the same law, where $A_1^{**}(x, y) = A_1(u + x, u + y)$. Such random matrices arise naturally in certain constructions of discrete-time particle systems and percolation models. The goal is to decide whether $(A_1A_2 \ldots A_n)(x, y)$ and $(A_1A_2 \ldots A_n)(x, y)$ tend to zero almost surely or in probability as n tends to infinity. The results presented here are based on subadditive ergodic theory, martingales, and Durrett's renormalization technique. [Received: 8 February 1989.]

211-3. **A PARADIGM FOR MODELING DELAY IN DISCRETE PATTERN RECOGNITION PROCESSES**

Thomas J. MARTINO, *Naval Underwater Systems Center, New London, Connecticut.*

A paradigm to assist in the stochastic modeling of processes involving delay in discrete pattern recognition processes is proposed. Relevant measures of performance are formulated and simulational approaches discussed. The suggested methodology has apparent applicability to industrial test and inspection schemes and to medical (diagnostic) testing. [Received: 30 January 1989.]

211-4. **A FUNCTIONAL CENTRAL LIMIT THEOREM FOR THE EWENS SAMPLING FORMULA**

Jennie C. HANSEN, *Tufts University, Medford, Massachusetts.*

For each $n > 0$, the Ewens sampling formula from population genetics determines a measure on the set of all partitions of the integer n. To study the limiting distributions of part sizes of a partition with respect to the measure determined by the sampling formula, we associate to each partition a step function on $[0, 1]$. Each jump in the associated function equals the number of parts in the partition of a certain size. We normalize these functions and show that the induced measures on $D[0, 1]$ converge to Wiener measure. This result complements Kingman's frequency limit theorem for the Ewens partition structure. [Received: 7 April 1989.]

211-5. **ON A STUDY OF CERTAIN POWER MIXTURES**

Wen-Jang HUANG and Li-Sue CHEN, *National Sun Yat-sen Univ., Kaohsiung, Taiwan.*

Let $Z = UX$, where X is some nonnegative random variable and U, independent of X, is beta distributed. Also, for any random variable Y, let $\phi_Y(t)$ denote the Laplace-Stieltjes transform (LST) of Y. We first characterize $\phi_X(t)$ for which $\phi_X(t)$ is a mixture of two certain powers of $\phi_X(t)$. Some other related problems are also solved. Then we discuss the distribution with LST$(1 + ct^c)^{-\lambda}$, $0 < c \leq 1$, a new distribution obtained in solving the above problems. [Received: 28 March 1989.]

211-6. **SOME EXAMPLES OF POISSON APPROXIMATION BY THE STEIN-CHEN METHOD AND COUPLING**

Lars K. HOLST, *Royal Institute of Technology, Stockholm.*

Let W be a sum of n (dependent) Bernoulli random variables. Using the Stein-Chen method, upper bounds for the variation distance between $\mathcal{L}(W)$ and *Poisson* ($\mathcal{E}(W)$) are given in Barbour and Holst [*Adv. Appl. Probab.* (1989)]. Under the existence of certain monotone couplings, these bounds involve essentially only $\mathcal{E}(W)$ and Var(W). The usefulness of this approach to Poisson approximation will be illustrated by some simple concrete examples. [Received: 5 April 1989.]

211-7. **AN URN MODEL AND THE COALESCENT IN NEUTRAL INFINITE-ALLELES GENETIC PROCESSES**

David BRANSON, *University of Essex, Colchester, England.*

An urn model, based on a variation of Kingman's coalescent, is defined within the context of infinite-alleles genetic processes incorporating selective neutrality. The model mimics the procedure of tracing a sample's ancestry backwards in time, noting the appearance of common ancestors or new mutants. The structure of the model is possessed by Moran's model, the Wright-Fisher model, and a time-inhomogeneous linear birth-and-death model with immigration. Elementary combinatorial arguments connected with the partial or complete emptying of the urn give rise to results that can be interpreted in terms of the allelic composition of genetic samples and populations. [Received: 4 April 1989.]

211-8. **DEGENERATE AND POISSON CONVERGENCE CRITERIA FOR SUCCESS RUNS**

Anant P. GODBOLE, *Michigan Technological University, Houghton.*

Let $N_n^{(k)}$ be the number of success runs of length $k > 1$ in n Bernoulli (p_n) trials. A formula is established for $P(N_n^{(k)} = x)$ that is an alternative to the one obtained by Philippou and Makri [*Statist. Probab. Letters* 4(1986):211-215]. Similarly, different formulae are obtained for the geometric, negative binomial and Poisson distributions of order k [Philippou, Georghiou and Philippou, *Statist. Probab. Letters* 1(1983):171-175]. It is shown that $N_n^{(k)}$ converges weakly to a degenerate distribution if $nf(p_n) \to \lambda$, where f is any function such that $p_n^k = o(f(p_n))$. This decides an open problem of Philippou and Makri in the negative. If, instead, $np_n^k \to \lambda$, we prove that $N_n^{(k)}$ tends in law to a Poisson (λ) random variable. This improves a classical theorem of von Mises which required, in addition, that $k \to \infty$. Rates of convergence are provided for the above results. [Received: 7 April 1989.]

211-9. **TESTS FOR GENE CONVERSION**

Stanley SAWYER, *Washington University, St. Louis, Missouri.*

Gene conversion is the nonreciprocal copying of a segment of DNA from one chromosome (or creature) to another, and seems to be an important part of nature. Models and nonparametric tests for a history of gene conversion within a sample of DNA sequences are discussed. It appears that gene conversion involving segments of 200bp or less may be more common in some organisms than point mutations. [Received: 12 April 1989.]

211-10. **COMPUTER ALGEBRA, BROWNIAN MOTION, AND THE STATISTICS OF SHAPE**

Wilfrid S. KENDALL, *University of Warwick, Coventry, England.*

Computer algebra opens up exciting opportunities for probabilists and statisticians. Powerful but (relatively) cheap computers can now be used to carry out exhausting and exhaustive calculations in a routine and fairly trouble-free manner, enormously extending one's capabilities as a mathematical scientist. At a deeper level the computer can be used to implement the geometric and logical structure of a theory, giving even greater opportunities for interactive computer-aided investigation. I shall illustrate these claims by describing an application of computer algebra in probability theory; the implementation of the Itô calculus of random processes using the computer algebra package REDUCE. In particular I shall discuss a recent application of REDUCE to the statistical theory of shape [D.G. Kendall, *Adv. Appl. Probab.* 9(1977):428-430], by which means can be derived an explicit description of the general Euclidean shape diffusion produced by k points diffusing in n dimensions [W.S.Kendall, *Adv. Appl. Probab.* 20(1988):775-797]. [Received: 1 April 1989.]

211-11. **PARTIAL OBSERVATIONS, PARTIAL MODEL SPECIFICATION, AND THE STRUCTURE OF LIKELIHOOD FOR POINT PROCESSES**

Elja ARJAS and P. HAARA, *University of Oulu, Finland.*

Marked point processes provide a convenient framework for the statistical modeling of longitudinal observations. Frequently, however, the observed data correspond poorly to what the investigator actually wants to know. For example, in animal carcinogenicity experiments the observed censoring times and the times at which sacrificing takes place are not of direct inferential interest, and the statistician would rather avoid completely the task of specifying the contribution

of the censoring and the sacrificing mechanism to the likelihood. On the other hand, for occult tumors the actual outcome of interest, tumor onset, cannot be observed. We discuss this in the general framework of filtering from a marked point process and show how the natural likelihood and prevalence expressions can be derived under minimal structural assumptions. [Received: 6 April 1989.]

211-12. **ANALYSIS OF INFECTIOUS DISEASE DATA FROM A SAMPLE OF HOUSEHOLDS**

Niels G. BECKER, *La Trobe University, Australia.*

Observations are made on the individuals from a sample of households at time points s and t. At time s it is determined who is susceptible to a certain infectious disease; at time t it is determined which of the susceptibles has been infected since time s. Infection may occur as a result of contacts within the household or from contact with other members of the community. A method for the analysis of such data is derived with the aid of martingale theory applied to a suitable epidemic model. This method of analysis is based on less restrictive assumptions than a previously proposed method for a similar epidemic model. The proposed method of analysis requires only a modest amount of calculation for its implementation. An application to influenza data is given. [Received: 10 April 1989.]

211-13. **AN URN MODEL FOR THE PROBABILITY OF A BOY**

Fergus DALY, *The Open University, Milton Keynes, England.*

The size of a family and the distribution of the sexes within it have long attracted the attentions of sociologists, demographers and statisticians. There are generally supposed to be four main sources of variation: Lexian variation (where the probability of a boy is different for different sets of parents); Poisson variation (where the probability of a boy varies with birth order); Markov variation (where the probability of a boy depends on the sex of previous births); and variation due to parents' stopping rules for family limitation. In this talk an urn-type probability model is suggested to represent some of these ideas. [Received: 30 March 1989.]

211-14. **MORE ON PORTFOLIO SELECTION WITH TRANSACTION COSTS**

M.H.A. DAVIS, *Imperial College, London.*

In a recent paper, the author and A. R. Norman solved a problem of optimal consumption and investment, in a model similar to that proposed by R. C. Merton, when proportional costs are imposed on all transactions in and out of stock. In this paper, various ramifications of this and related results are considered. Specifically, we analyze the "small transaction cost" case with a view to calculating "liquidity premia," and we also consider the case in which fixed as well as proportional costs are imposed. [Received: 21 March 1989.]

211-15. **ESTIMATING THE EXTREME-VALUE INDEX**

L. de HAAN, *Erasmus University, Rotterdam, The Netherlands.*

A combination of linear and quadratic functions of upper and intermediate order statistics is proposed as an estimator for the index gamma of an extreme-value distribution if the observations are taken from a distribution in its domain of attraction. Consistency and asymptotic normality are shown under certain conditions. The optimal choice for the number of order statistics involved is discussed. [Received: 10 April 1989.]

211-16. **THE TWO LOCUS INFINITELY-MANY-ALLELES MODEL AND THE ANCESTRAL TREE OF A SAMPLE OF GENES**

R.C. GRIFFITHS, *Monash University*, and S.N. ETHIER, *University of Utah*.

A well-explored model in population genetics is the infinitely-many-alleles-model. The probability distribution of the configuration of a sample of genes grouped according to allele type is known as the Ewens sampling formula. Extension to a 2-locus model with recombination allows some numerical calculation of probability distributions associated with a sample of pairs of loci. The coalescent process of Kingman describes how ancestors of a sample coalesce, eventually to a common ancestor, at a single locus. In a 2-locus model with recombination, an offspring may be a recombinant from two parents, so the number of "ancestors" of a sample can increase or decrease back in time, producing an interesting ancestral tree process. [Received: 1 April 1989.]

211-17. **MULTI-LEVEL BRANCHING AS A MEASURE-VALUED PROCESS**

Kenneth J. HOCHBERG, *Bar-Ilan University, Ramat-Gan, Israel*, and Donald A. DAWSON, *Carleton University, Ottawa*.

We consider measure-valued processes arising in the study of multi-level information structures. At both the individual and colony levels, information units undergo Galton-Watson-type branching. We analyze the moment structure and the long-term behavior of the resulting measure-valued process and consider a continuous-state-space limiting version for subcritical, critical, and supercritical behavior at each level. Results include asymptotics for the extinction probability and a conditional limit law for the total population mass. Examples arise in descriptions of animal and plant evolution, DNA structure, and replication of digitized data collections. [Received: 4 April 1989.]

211-18. **MARKOV PROPERTIES FOR POINT PROCESSES ON THE PLANE**

Ely MERZBACH and David NUALART, *Bar-Ilan University, Ramat-Gan, Israel*.

We prove that for a wide class of point processes indexed by the positive quadrant of the plane, and for a class of compact sets in this quadrant, the germ sigma-field is equal to the sigma-field generated by the values of the process on the set. Therefore, there exists a large family of point processes on the plane (and among them the spatial Poisson process) which satisfy the sharp Markov property in the sense of Paul Lévy. The strong Markov property with respect to stopping lines is also studied. Some examples are obtained by taking transformations of the probability measure. [Received: 5 April 1989.]

211-19. **SADDLEPOINT APPROXIMATIONS FOR INTRACTABLE CUMULANT GENERATING FUNCTIONS**

John E. KOLASSA, *University of Chicago*.

Saddlepoint approximations have long been used to approximate densities and distribution functions of random variables with known moment generating function defined on an open interval about the origin. This approximation has very desirable asymptotic properties when approximating densities and tail probabilities for sums of random variables, and also often performs remarkably well for small sample sizes, including samples of size one. Calculating the saddlepoint approximation requires calculating the Legendre transform of the log of the moment generating function. Often this transform is difficult to calculate analytically. We discuss modifications to the saddlepoint approximation necessary when the moment generating function is replaced by a similar but more tractable function whose Legendre transform can be given explicitly. We present calculations for the logistic distribution and discuss an application to a random effects logistic linear model. [Received: 7 April 1989.]

211-20. **ESTIMATION IN LONG-MEMORY TIME SERIES MODELS**

Alexander SAMAROV, *University of Lowell and Massachusetts Institute of Technology*.

Long-memory time series are commonly modeled by stationary processes with a pole or zero of the spectrum at the origin. In this paper we consider the problem of estimation of the order of that pole or zero. We study, in particular, asymptotic properties of the estimator based on the linear least-squares regression of the log periodogram on low Fourier frequencies (Geweke and Porter-Hudak, *J. Time Series Anal.* 4(1983):221-238). We find the range of frequencies for which this estimator has the best rate of convergence. It turns out, in particular, that one should not regress on the frequencies too close to 0. We also compare this estimator with estimators obtained by other methods. [Received: 11 April 1989.]

211-21. **THE DISTRIBUTIONS OF CERTAIN RECORD STATISTICS FROM A RANDOM NUMBER OF OBSERVATIONS**

John A. BUNGE, Kenyon College, Gambier, Ohio, and H.N. NAGARAJA, *Ohio State University, Columbus*.

Suppose we observe a random number N of independent identically distributed random variables in sequence. The record values are the successive maxima of this sequence. Assuming that N and the observations are independent, we obtain the joint distribution of the number of records and their values. Our results are applied to models considered by Gaver [*J. Appl. Probab.* 13(1976):538-547] and Westcott [*Proc. Roy. Soc. Lond. Ser. A* 356(1977):529-547], in which the random variables occur at the arrival times of an independent point process. We can relax the assumption of identical distribution of the observations to allow the distribution to change after a record event, as proposed by Pfeifer [*J. Appl. Probab.* 19(1982):127-135]. [Received: 11 April 1989.]

211-22. **ON THE DISTRIBUTION OF THE SUM OF TWO DISCRETE UNIFORM RANDOM VARIABLES WITH APPLICATIONS**

S.A. PATIL, *Tennessee Technological University, Cookeville*.

The probability density function of the sum of two uniform discrete random variables is determined. This distribution function of the sum of two random variables is obtained. The distribution function is used to determine the probability distributions of the first digit and the first k digits. The moment, and moment generating function for the sum of two discrete uniform distributions are stated. The distribution of the sum of two random variables is used to find the probability of winning in the game of craps with n-sided dice. The limit of this probability when n goes to ∞ is determined in closed form. The probability of the game of craps when the rules of winning depend on n is obtained and limiting values determined. [Received: 11 April 1989.]

211-23. MODELING AND INFERENCE FOR RAINFALL FIELDS

Michael J. PHELAN, *Princeton University.*

The WGR model represents rainfall fields by a smoothing transformation of a Poisson-based cluster point process. We assess the geometry and kinematics of this model entailed by its choice of smoothing kernel. The analysis suggests the need to better handle ageing and dissipation in precipitative systems. We introduce and explore the role of ageing processes for convective raincells based on processes of independent increments. [Received: 11 April 1989.]

211-24. INTERACTING PARTICLE SYSTEMS INSPIRED BY BIOLOGY

Richard DURRETT, *Cornell University, Ithaca.*

We will describe recent results on the contact process and related models. As the title suggests the processes to be considered were inspired by biological systems. [Received: 12 April 1989.]

211-25. TESTING FOR INHERITANCE OF DISEASE

J.R. GREEN, *University of Liverpool, Liverpool, England.*

The usual way to test for the inheritance of a disease-susceptibility gene is by looking for a significant sharing of a haplotype among the affected siblings of a sibship. There are a few measures of the amount of sharing (haplotype concordance) of haplotypes from the four haplotype combinations available in each sibship. The different measures are compared, and the use of the best one described, also the use of a measure of discordance for cases where there is only one affected and at least one unaffected sibling. [Received: 13 April 1989.]

211-26. THE BIOLOGY OF RANDOM PERMUTATIONS

Simon TAVARÉ, *University of Utah, Salt Lake City.*

Permutation-valued Markov processes provide a convenient way to describe the genealogical structure of certain population models that allow immigration or mutation. Distinct cycles of the permutation correspond to binary branching trees that describe relationships among members of a particular family (or copies of an allele in the genetics setting). The ordering of the cycles corresponds to families (or alleles) in the order of their appearance in the population. I will describe the structure of these processes, and highlight the interplay between properties of permutations and results from the neutral theory of population genetics. Connections with Kingman's coalescent and the asymptotic behavior of permutations and genealogy will also be described. [Received: 13 April 1989.]

211-27. WEAK CONVERGENCE OF ANCESTRAL PROCESSES IN POPULATION GENETICS

Peter J. DONNELLY, *Queen Mary College, London.*

We prove that the population ancestral processes associated with a wide class of neutral exchangeable models (i.e., the processes which, going backwards in time, count the number of ancestors of the population) converge weakly (after the usual time rescaling) to a death process with an entrance boundary at infinity and death rates $k(k-1)/2$ from state k. This settles a conjecture of Kingman and facilitates the completion of the robustness theory for population genealogical processes in neutral models. From a technical point of view the problem, and the limiting process (with an entrance boundary which is the accumulation point of a countable state space), appear non-standard and the techniques rely heavily on monotonicity properties and knowledge of sample behavior. Corollaries include weak convergence of the absorption times of many neutral genetic models to that of the Wright-Fisher diffusion and also weak convergence of population line-of-descent processes to another death process. [Received: 13 April 1989.]

211-28. ARBITRAGE AND MARTINGALES

David C. HEATH, *Cornell University, Ithaca, New York.*

The collection of stochastic processes which reasonably model prices in financial markets consists of those which do not allow arbitrage, i.e., do not allow a trader (using allowed trading rules) to win with positive probability while having probability zero of losing. Martingales have this property; conversely, it is known under certain circumstances that each process having this property is, under an equivalent measure, a martingale. The conditions under which such equivalent martingale measures must exist appear to be far too restrictive; it is possible that a very general result holds. In addition to verifying the no-arbitrage condition, equivalent martingale measures sometimes simplify structure and proofs. [Received: 13 April 1989.]

211-29. TESTS FOR THE CHARACTERISTIC EXPONENT IN A CLASS OF STABLE DISTRIBUTIONS

Helena Iglésias PEREIRA, *University of Lisbon, Lisboa, Portugal.*

In the class of stable distributions $S(\alpha, \beta, a, c)$, where $\alpha \in (0, 2]$, $-1 \le \beta \le 1$, $a \in \mathbb{R}$ and $c > 0$ are the characteristic exponent (c.e.), the skewness, the location and scale parameters respectively, we develop tests for the c.e. α and the scale parameter c of a symmetric stable random variable $S(\alpha, 0, 0, c)$. The test statistics for the hypothesis H_0: $\alpha = \alpha_0$ vs. H_1: $\alpha > \alpha_0$ (resp. $\alpha < \alpha_0$) and H_0: $c = c_0$ vs. H_1: $c > c_0$ (resp. $c < c_0$) are functions of the empirical characteristic function $\phi_n(t) = n^{-1}\sum_j \exp(itx_j)$, where $x_1, \ldots, x_n$ constitute a random sample of size n from a stable population $S(\alpha, 0, 0, c)$. We study the asymptotic properties of the power functions $P_n(\alpha)$ and $P_n(c)$ when n goes to infinity and also their behavior in the neighborhood of α_0 and c_0. [Received: 14 April 1989.]

211-30. PRICE VOLATILITY IN A DYNAMIC SECURITIES MARKET

Roger HARTLEY, *University of Keele, Keele, England.*

We describe a model designed to analyze price behaviour in a dynamic, stochastic model of a securities market, with costly information acquisition. We assume that dividends are described by a discrete-time, Gaussian, Markov (for simplicity only) process and agents' demands are determined by the objective of maximizing the future, discounted sum of expected (exponential) utility of the dividend stream they receive over the (infinite) future. Transitions are also perturbed by a noise term whose value can be purchased at a cost $c > 0$. Supply of securities is described by a stationary Gaussian process, which is determined by liquidity traders exogenous to the model. Prices solve a partially revealing, temporary, rational expectations equilibrium in which the excess return obtained by informed traders is equal to the cost of information. This model can be formulated as an adaptive, dynamic programming problem and we show how this formulation enables it to be solved to find the price process. A major objective of this study is to investigate the volatility of prices and so a sensitivity analysis is conducted, focusing particularly on the variance of the market index. We show that this variance can increase as c decreases and, therefore, the number of informed participants increases. The model is a major extension of that of Grossman and Siglitz [*AER* 70(1980)] (for which the previous result is invalid) and of Black and Tonks's recent and unpublished two-period model which has only a terminal dividend payment. [Received: 12 April 1989.]

211-31. **ANNIHILATING AND COALESCING PARTICLE SYSTEMS: MODELS OF DIFFUSION-LIMITED REACTIONS**

David BALDING, *University of Oxford.*

Traditional, deterministic models of diffusion-limited reactions are based on simplifying assumptions about the spatial structure of the reacting particles, assumptions whose validity is difficult to assess but which are known to be inappropriate in many important cases. Systems of annihilating or coalescing random walks on Z or Brownian motions on R provide stochastic models of such reactions for which, with arbitrary initial configurations of particles, the exact evolution of the reaction can be described in detail. The asymptotic behaviour of these systems is derived in terms of the structure of the initial configuration and the results are compared with the predictions of a deterministic formulation. [Received: 17 April 1989.]

211-32. **ON THE DIFFUSIVE BEHAVIOR OF DIRECTED POLYMERS IN RANDOM ENVIRONMENTS**

Erwin BOLTHAUSEN, *Technische Universität, Berlin.*

A simple martingale approach to the diffusive behavior of directed polymers in random environments in high dimensions and at low disorder is presented. The model is the following one: Let $X(t, i)$, for each time point t (in N) and each point i in the d-dimensional lattice, be positive random variables with expectation 1 and finite variance. They are assumed to be independent and identically distributed. Each nearest neighbour path $w(0) = 0, w(1), \ldots, w(T)$ on the lattice gets, for a fixed realization of the X-variables, the relative weight $X(1, w(1))X(2, w(2))\ldots X(T, w(T))$. Imbrie and Spencer [*J. Statist. Phys.* 52:609] proved in a special case that for $d \geq 3$ and if the variance of the X-variables is small enough, one has for almost all realizations of these variables (the random environment) that the mean square displacement of $w(T)$ divided by T converges to 1 when $T \to \infty$. The proof was given by cluster expansion techniques. There is a simple martingale argument for this which also gives a central limit theorem. [Received: 14 April 1989.]

211-33. ***U*-STATISTICS FOR LONG-RANGE DEPENDENT OBSERVATIONS**

Herold DEHLING, *Universiteit Groningen, The Netherlands,*
and Murad S. TAQQU, *Boston University.*

We obtain the limit distribution of certain symmetric statistics of long-range dependent observations. Several examples of practical interest are studied: the usual variance estimator, chi-squared goodness-of-fit test, Cramér-von Mises-Smirnov statistic. The results differ markedly from the classical ones obtained for independent or weakly dependent observations. The identification of possible limits has interesting connections with properties of orthogonal polynomials. [Received: 15 April 1989.]

211-34. **RANDOM WALKS, EMBEDDED BRANCHING PROCESSES AND QUEUES**

Michael SHALMON, *INRS Telecommunications, Université du Québec à Montréal.*

We present a new probabilistic approach to the analysis of the single server queue and its variations, and in particular of queues with Poisson arrivals. The approach is based on sample path averaging and on a sample path decomposition. The decomposition can be interpreted in terms of the ladder variables of the associated random walk, or alternatively in terms of the LCFS discipline. For the M/G/1 queue, the decomposition is further interpreted in terms of a birth-death branching process. The derivations of the transient and stationary distributions, and of the Poisson departure property (for LCFS preemptive resume) are simple and insightful. The set-up easily extends to more elaborate models (server vacations, multiple prioritized inputs, bounded queue, variable service and arrival rates). Finally, we show that unidirectional tandem and tree networks of queues with deterministic service (modelling simple packet-switching concentrating networks) can be analyzed similarly. The exact delays are much less than those obtained by approximating the internal flow in the network by a Poisson process; this is so even for the mean values. [Received: 15 April 1989.]

211-35. **CONTINUOUS-TIME RECURSIVE UTILITY**

Darrell DUFFIE, *Stanford University,*
and Larry EPSTEIN, *University of Toronto.*

Included are a formulation and properties of recursive utility functions in continuous-time settings under uncertainty. Existence and uniqueness are presented in a Markov setting. As an application, homothetic epresentative-agent recursive utility functions are shown to imply that excess returns on securities are given by a linear combination of the continuous-time market-portfolio based CAPM and the consumption-based CAPM. [Received: 15 April 1989.]

211-36. **APPLICATION OF THE STEIN-CHEN METHOD TO MATERIALS STRENGTH PROBLEMS**

Richard L. SMITH and S. Leigh PHOENIX, *University of Surrey, Guildford, England.*

The Stein-Chen method [*Proc. Sixth Berkeley Symp.* 2(1970):583-602; *Ann. Probab.* 3(1975): 534-545] is a powerful technique for proving limit theorems and obtaining error bounds in Poisson approximation. The first author has previously used it to re-derive some general results on extremes in dependent sequences [*Stoch. Proc. Appl.* 30(1988):317-327]. The present study is concerned with the strength of a lattice material in which individual elements have random strength 0 or 1 but there are interactions among the elements. Intuitive arguments, based on the notion that clusters of 0-strength elements will determine the strength of the system, suggest approximations to the distribution of system strength. The Stein-Chen method provides a compact method of verifying such approximations and also suggests ways of improving the approximation. [Received: 15 April 1989.]

211-37. **THE STRUCTURE OF EPIDEMIC MODELS**

Denis MOLLISON, *Heriot-Watt University, Edinburgh, Scotland.*

The themes of the talk will be: first, the sensitivity of results to assumptions, and hence the importance of looking carefully at their dependence, not only on the values of parameters but also on the structure of the model (for instance, deterministic/stochastic, discrete/continuous time, homogeneous/heterogeneous mixing). Second, the importance of keeping models clear and simple, as far as possible, and of expressing them in terms of basic ecological parameters, such as the basic reproduction ratio and the generation gap of the disease. These themes will be illustrated by discussion of a "pre-model," differential and difference equations, and spatial stochastic models for the spread of rabies [*Philos. Trans. Roy. Soc. Ser. B* 314(1986):675-693; and Cox and Durrett, *Stoch. Proc. Appl.* 30(1988):171-191]. A third, rather different, theme is the possibility of making use of the detailed structure of stochastic models. The distinction will be made between the minimal "surface description" of a process, and more detailed "internal descriptions" [Barbour and Mollison, *Stochastic Theory of Epidemic Models* (1989)]. One of the results for the Reed-Frost epidemic which follows immediately from its relation to $G(n, p)$ is that the probability of a large outbreak is equal to the proportion of the population affected if a large outbreak occurs. This extends to provide insights into the spread of similar epidemic processes in grouped populations. More general random graph models will be discussed briefly, including the idea of characterising the contact graph by "triangle" probabilities; for instance, if "ab" denotes that a has an infectious link to b, $\text{Prob}[ac \mid ab \cap bc]/\text{Prob}[ac] = 1$ for $G(n, p)$, but $= O(n)$ for a model with spatially local contacts. [Received: 21 April 1989.]

211-38. **RESAMPLING METHODS FOR DEPENDENT DATA**

Ishwar V. BASAWA, University of Georgia, Athens.

Efron's bootstrap has proved to be a useful resampling method of approximating sampling distributions of various estimates and test statistics. The bootstrap has been applied in problems predominantly involving independent observations. Extension of this method to specific types of dependent data provides a new direction of research in this area. One typically establishes asymptotic validity of the bootstrap by showing that the limiting conditional distribution of the bootstrapped statistic given the sample is the same as the unconditional limit distribution of the original statistic for almost all sample paths. Asymptotic validity of the bootstrap will be established for a class of estimators and test statistics in finite Markov chains, and nonstationary autoregressive processes. The talk will emphasize basic ideas and methods rather than technical details. [Received: 21 April 1989.]

211-39. **COMBINATORIAL OPTIMIZATION AND PROBABILITY THEORY**

J. Michael STEELE, *Princeton University.*

We review some recent developments in combinatorial optimization that make use of probability theory. By martingale and other methods we find that objective functions for random problems are often tightly concentrated about their means. This natural phenomenon is examined for the guidance it gives about algorithms. [Received: 21 April 1989.]

211-40. **MARTINGALE CONVERGENCE IN BRANCHING RANDOM WALKS**

J.D. BIGGINS, *University of Sheffield, Sheffield, England.*

In the supercritical branching random walk an initial person has children whose positions are given by a point process Z. Each of these then has children in the same way, with the positions of children in each family, relative to their parents', being given by independent copies of Z, and so on. For any value of its argument the Laplace transform of the point process of nth generation people, normalized by its expected value, is a martingale, the usual branching process martingale being a special case. A new result on the convergence of these martingales will be described and its application in establishing the asymptotics of the nth generation point process, as n goes to infinity, indicated. [Received: 26 April 1989.]

211-41. **PATTERNS OF EVOLUTIONARILY STABLE STRATEGIES**

Chris CANNINGS and G.T. VICKERS, *University of Sheffield, Sheffield, England.*

The theory of animal conflicts applies a game-theory like approach to the study of behavioural strategies. The fundamental concept is that of an ESS (evolutionarily stable strategy) [Maynard-Smith and Price, *Nature* 245(1973):15-18]. For a finite conflict, where payoffs are represented as a payoff-matrix, there are, unlike finite zero-sum games, potentially many ESS's. The set of supports of the ESS's of a given matrix is a subset of the power set of the space of pure strategies. Certain of these subsets (patterns) are not attained for any payoff matrix. The authors, in a series of papers, have attempted to define the attainable and impossible patterns. A selection of these results will be presented. [Received: 26 April 1989.]

211-42. **EXTINCTION PROBABILITIES OF BRANCHING PROCESSES IN RANDOM ENVIRONMENTS**

D.R. GREY and Lu ZHUNWEI, *University of Sheffield, Sheffield, England.*

In a branching process with stationary ergodic environments, the probability of ultimate extinction starting with k individuals is the kth moment of the distribution of the extinction probability starting with one individual. It may also be identified as the kth moment of the equilibrium distribution of a dual process first introduced by Smith and Wilkinson in the special case of independent and identically distributed environments. This fact is used to estimate the behaviour of the extinction probability as k tends to infinity. [Received: 26 April 1989.]

211-43. **THE CALIBRATION PROBLEM AS AN ILL-POSED INVERSE PROBLEM**

Charles HAGWOOD, *NIST, Bethesda, Maryland.*

Let (x_i, y_i), $i = 1, 2, \ldots, n$, be data used for developing the calibration curve, $y = \hat{\alpha} + \hat{\beta}x$. Classically, given a future y' the associated x' is estimated by inverting the calibration line, which gives gives the estimate $\hat{x}' = (y' - \hat{\alpha})/\hat{\beta}$. This estimate has infinite variance, because the inversion is done with noisy data. We use the techniques for solving ill-posed inverse problems to develop a solution $\hat{x}' = \hat{\beta}\lambda + \hat{\beta}^2(y' - \hat{\alpha})$, with finite variance and other good properties. [Received: 26 April 1989.]

211-44. **U-STATISTICS AND THE DOUBLE STABLE INTEGRAL**

Joop MIJNHEER, *Universiteit Leiden, The Netherlands.*

Multiple Wiener integrals appear in the theory of U-statistics. Several results are known for multiple integrals with respect to a symmetric stable process (or measure). We consider multiple integrals with respect to a completely asymmetric stable process. We compute the characteristic function, from which the tail behavior of the multiple integral is derived. This behavior is different from the symmetric case. [Received: 3 May 1989.]

211-45. **UNIQUENESS AND COUPLING PROPERTIES OF THE STATIONARY PRECEDENCE-BASED QUEUEING DISCIPLINE**

François BACCELLI, *INRIA, Valbonne, France,*
and Serguei FOSS, *Novosibirsk State University, Novosibirsk, USSR.*

We consider a queueing system with infinitely many servers, and with the following discipline: for any pair of customers i and j such that i arrived later than j, there is a fixed probability p that i will have to wait for j to terminate its execution before i starts. The general conditions under which this system is stable were established in [Baccelli and Lui, On the Stability of a Precedence Based Queueing Discipline, Rapport INRIA No. 880, July 1988, *J. Appl. Probab.*, to appear]. Here we establish the following additional properties: (1) If it is stable, the system has a unique stationary solution and whatever the initial condition, the sequence of waiting times (w_n) couples within finite time with its stationary version. (2) There exists a Palm space on which a subsequence imbedded in the sequence w_n satisfies a simple Lindley type recursion and the stability condition obtained precedently can be rewritten as the classical $G/G/1$ queue stability condition with respect to this Palm measure. [Received: 4 May 1989.]

211-46. **ON THE DIFFUSION OF PARTICLES IN SIMPLE FLUIDS**

Detlef DÜRR, *Universität München, München, Federal Republic of Germany.*

We review some problems arising from the study of the motion of test particles in (simple) fluids, noting that the weak coupling situation can be dealt with in a unifying way by martingale techniques. We then proceed to some open problems which are physically more relevant, and for which the right mathematical (or physical) input is lacking. [Received: 10 May 1989.]

211-47. **STRONG MODERATE DEVIATION THEOREMS FOR *m*-DEPENDENT RANDOM VARIABLES: PRELIMINARY REPORT**

N.R. CHAGANTY, *Old Dominion University, Norfolk, Virginia.*

Consider a stationary sequence $\{X_1, X_2, \ldots\}$ of m-dependent random variables. Let $S_n = \sum_{i=1}^{n} X_i$ be the partial sum. Under some moment conditions, we obtain asymptotic expressions for the probability of moderate deviations, $P(S_n > x_n)$, where $x_n = O(\sqrt{\log(n)})$. These extend some well known results for independent and identically distributed sequences of random variables. Extensions of our results to L-statistics and U-statistics is under investigation. [Received: 26 January 1989.]

211-48. **STRONG LAWS OF LARGE NUMBERS FOR WEIGHTED SUMS OF RANDOM ELEMENTS IN NORMED LINEAR SPACES**

André ADLER, *Illinois Institute of Technology, Chicago,*
Andrew ROSALSKY, *University of Florida, Gainesville,*
and Robert L. TAYLOR, *University of Georgia, Athens.*

Consider a sequence of independent random elements $(V_n, n \geq 1)$ in a real separable normed linear space X (assumed to be a Banach space in most of the results), and sequences of constants $(a_n, n \geq 1)$ and $(b_n, n \geq 1)$ with $0 < b_n \uparrow \infty$. Sets of conditions are provided for $(a_n(V_n - \mathcal{E}V_n), n \geq 1)$ to obey a general strong law of large numbers of the form $\sum_{j=1}^{n} a_n(V_j - \mathcal{E}V_j)/b_n \to 0$ almost certainly. The hypotheses involve the distributions of the $(V_n, n \geq 1)$, the growth behaviors of $(a_n, n \geq 1)$ and $(b_n, n \geq 1)$, and for some of the results impose a geometric condition on X. Moreover, Feller's classical result generalizing the Marcinkiewicz-Zygmund strong law of large numbers is shown to hold for random elements in a real separable Rademacher type p $(1 < p \leq 2)$ Banach space. [Received: 15 March 1989.]

211-49. **STRONG CONVERGENCE FOR SUMS OF RANDOMLY WEIGHTED, ROWWISE EXCHANGEABLE RANDOM ELEMENTS**

Ronald P. PATTERSON, *Georgia State University, Atlanta,*
Robert L. TAYLOR, *University of Georgia, Athens,*
and Hiroshi INOUE, *Science University of Tokyo, Kokkaido, Japan.*

Let $\{X_{nk}: 1 \leq k \leq n, n \geq 1\}$ be an array of rowwise exchangeable random elements in a separable Banach space. Let $\{A_n\}$ and $\{a_n\}$ be random variables where A_n is positive and a_n is a symmetric function of $(X_{n1}, \ldots, X_{nn})$. Using reverse martingale techniques, strong convergence is obtained for the weighted sum, $A_n^{-1} \sum_{k=1}^{n} a_n X_{nk}$, under suitable conditions on the random elements and suitable conditions on the random weights. [Received: 15 March 1989.]

211-50. **FIRST PASSAGE TIMES IN NONLINEAR RENEWAL THEORY**

Allan GUT, *Uppsala Universitet, Uppsala, Sweden.*

Let $X_1, X_2, \ldots$ be independent and identically distributed random variables with positive, finite mean μ and set the random walk $S_n = \sum_{k=1}^{n} X_k$, $n \geq 1$. Further, let $\{\xi_n, n \geq 1\}$ be a sequence of random variables such that, for each n, ξ_n is independent of $\{X_k, k > n\}$ and set $Z_n = S_n + \xi_n$, $n \geq 1$. Nonlinear renewal theory is concerned with the family of first passage times $\{\nu(t), t \geq 0\}$,

defined by $\nu(t) = \min\{n: Z_n > t\}$, under the assumption that $\{\xi_n, n \geq 1\}$ is slowly changing, that is, provided that $n^{-1}\max_{1 \leq k \leq n} |\xi_k| \to 0$ in probability as $n \to \infty$ and that, ξ_n, $n \geq 1$, are uniformly continuous in probability. The assumption that $\{\xi_n, n \geq 1\}$ is slowly changing makes it natural to call $\{Z_n, n \geq 1\}$ a perturbed random walk. We consider the important special case when $Z_n = ng(S_n/n)$, $n \geq 1$, i.e., when $\nu(t) = \min\{n: ng(S_n/n) > t\}$, $t \geq 0$, under the assumption that the function g is positive, convex and twice continuously differentiable (in some neighborhood of μ). After some examples we establish conditions for finiteness of the moments of the first passage times, the stopped process and the overshoot and asymptotics for these as $t \to \infty$. We further prove strong laws, a central limit theorem, results on uniform integrability and moment convergence and a law of the iterated logarithm for $\{\nu(t), t \geq 0\}$. Finally, we discuss to what extent (some of) our results remain valid for general perturbed random walks. The proofs are based on the method of stopped random walks [Gut, *Stopped Random Walks: Limit Theorems and Applications*. Springer, New York (1988)]. [Received: 7 April 1989.]

211-51. **IMAGE RECONSTRUCTION – A NEW CLASS OF PRIORS**

Richard D. MIDDLETON, *University of Oxford.*

We consider statistical problems arising from the analysis of images with large-scale linear features. Examples include the identification of artificial structures from satellite data and the description of pressure-ridge systems in sea ice. Markov random fields on lattices are currently being used as statistical models for digitised images. Such models are pixel-based, and the image is typically recorded as a 256×256 array of real numbers. Here we consider a new description, based on polygonal Markov random fields. These are constructed from the Poisson line process. Realisations are random sets with straight line segments as boundaries. In this talk, no previous acquaintance with image processing or stochastic geometry will be assumed. We discuss image reconstruction in a Bayesian framework, and investigate the feasibility of using simulated annealing as a means of obtaining maximum a posteriori (MAP) estimates. [Received: 17 May 1989.]

211-52. **A LOOK AT PERTURBATION APPROXIMATIONS FOR EPIDEMICS**

Henry E. DANIELS, *University of Cambridge.*

Perturbation techniques have been applied by various authors to epidemics and related problems [Bailey, *Biometrika* 55(1968):199-209; Weiss, *Adv. Appl. Probab.* 3(1971):220-221; Barbour, *J. Appl. Probab.* 9(1972):519-541]. Here an attempt is made to develop a unified technique using standard perturbation procedures to approximate to the mean and variance of epidemic paths. For simple epidemics of various kinds with no removals, the saddlepoint approximation to the distribution of infectives is highly accurate for quite small populations and can be used to assess the accuracy of perturbation approximations. In the case of the standard epidemic model with removals, no saddlepoint approximation is available and simulations have to be used for comparison with the perturbation results. [Received: 22 May 1989.]

Stationary self-similar extremal processes

*George L. O'Brien**
Paul J. J. F. Torfs
Wim Vervaat

York University, North York, Ontario, Canada
Agricultural University, Wageningen, The Netherlands
Catholic University, Nijmegen, The Netherlands

Abstract. Let $(\xi_k)_{k=-\infty}^{\infty}$ be a stationary sequence of random variables, and, for $A \subset \mathbb{R}$, let $M_n(A) := \bigvee_{k/n \in A} \gamma_n(\xi_k)$ where γ_n is an affine transformation of $\mathbb{R}$ (has the form $a_n \cdot + b_n$, $a_n > 0$, $b \in \mathbb{R}$). Then M_n is a random sup measure, that is, $M_n(\bigcup_\alpha G_\alpha) = \bigvee_\alpha M_n(G_\alpha)$ for arbitrary collections of open sets G_α. We show that the possible limiting random sup measures for such sequences (M_n) are those which are stationary $(M(\cdot + b) =_d M$ for $b \in \mathbb{R})$ and self-similar $(M(a \cdot) =_d \delta^{\log a}(M)$ for $a > 0$, where δ is an affine transformation of $\mathbb{R})$. By applying simple transformations, we need only study stationary M such that $M(a \cdot) =_d aM$ for $a > 0$. We show these processes retain some but not all of the properties of the classical case. In particular, we display a nontrivial example such that $t \mapsto M(0,t]$ is continuous wpl. The classical planar point process representation of extremal processes is a special case of the present approach, but is not adequate for describing all possible limits.

A linear random growth model

M.P. Quine

University of Sydney

The following growth model is of interest in particular in two distinct areas of biology: secretion of quanta at neuromuscular synapses and unravelling of strands of DNA. Points start to form on an "uncovered" unit interval according to a Poisson process with parameter λ. From newly formed points a covering region grows in both directions at velocity v, while new points continue to form an uncovered parts of the intervgal. Eventually the whole interval will be covered. We investigate the distribution of the number N of points formed, in particular the asymptotic behaviour as $\lambda/v \to \infty$.

A fluctuations limit for scaled age distributions

and

Weighted Sobolev spaces

by

A. Bose

Department of Mathematics and Statistics

Carleton University

Ottawa, CANADA K1S 5B6

ABSTRACT: It is shown that under the central limit scaling, the fluctuations of the space-time renormalized age distributions of particles (whose development is controlled by critical linear birth and death processes) around the law of large numbers limit converge in a Hilbert space (dual of a weighted Sobolev space containing the class of signed Radon measures with finite moment generating functionals) to a continuous Gaussian process satisfying a Langevin equation. So far, the space of rapidly decreasing functions has been considered to be the natural state space for the kind of limit theorem considered here. However, this space of rapidly decreasing funciton is not suitable in the present context and we are led to define a family of Sobolev spaces which are appropriate for our purpose.

Two queues with a single server

by

S E Hitchcock

Open University

ABSTRACT

Customers of two types form two separate queues which are served by a single server who always serves the longer queue first. The equilibrium distributions of the queue lengths are derived and the expected queue lengths and results about the busy period are given.

Building conditioned trees

Brigitte Chauvin
LABORATOIRE DE PROBABILITÉS
Tour 56 (3e étage) - 4, place Jussieu - 75252 PARIS CEDEX 05

Abstract : To illustrate once more the direct use of the branching property, a desintegration of the Campbell measure for a branching brownian motion is achieved. Working on a probability space of trees provides a fast identification of the "Palm" probability.

THE STATISTICAL THEORY OF SHAPE AND ITS APPLICATIONS

David G. KENDALL, *Cambridge, England.*

This is a survey covering most of the ground of my forthcoming article in *Statistical Science*, together with several more recent results.

ON ITERATED LOGARITHM LAW FOR THE MAXIMUM IN GAUSSIAN PROCESS

S. Y. TANG*

Department of probability & Statistics
University of Sheffield, U.K.

Abstract Let $\{X(t),\ -\infty < t < \infty\}$ denote a stationary Gaussian process with

$$EX(t) = 0,\ EX^2(t) = 1,\ EX(s)X(s+t) = r(t) \quad \text{for all } s,t,\ -\infty < s,t < \infty$$

and

$$r(t) = 1 - |t|^\alpha H(|t|) + o(|t|^\alpha H(|t|)), \quad \text{as } t \longrightarrow \infty,$$

where $0 < \alpha \leq 2$, H is a function that varies slowly at 0. Let $M(t) = \sup_{0 \leq s \leq t} X(s)$. We study the asymptotic properties of $M(t)$. Some iterated logarithm law for $M(t)$ was obtained:
Theorem 1. If $\lim_{t \to \infty} t^\alpha r(t) = 0$, for some λ, then

$$P\{M(t) \geq g(t) \text{ i.o.} t \uparrow \infty) = 0 \quad \text{as } \delta > 0;$$

$$P\{M(t) \geq g(t) \text{ i.o.} t \uparrow \infty\} = 1 \quad \text{as} \delta \leq 0.$$

where $g(t) = [2\log t/2\sqrt{2} + (2/\alpha + 1)\log_2 t + 2(\log_3 t + \ldots + \log_k t + (1+\delta)\log_{k+1} t]^{1/2}$
(2) Let

$$h(t) = [2\log t/K(\alpha, C) + (2/\alpha - 1)\log_2 t - 2\log\log_2 t + 2\log_3 t + \sum_{i=4}^{k} \log_i(t + (1+\delta))\log_{k+1} t]^{1/2}$$

where $K(\alpha, C)$ is positive constant. Then

$$P\{M(t) \leq h(t) \text{ i.o.} t \uparrow \infty\} = 0 \quad \text{as } \delta > 0$$

and guess

$$P\{M(t) \leq h(t) \text{ i.o.} t \uparrow) = 1 \quad \text{as } \delta \leq 0$$

Theorem 2. If $\lim_{t \to \infty} t^\lambda r(t) = 0$, for some λ, then

$$\lim_{t \to \infty} sup \frac{(2\log t)^{1/2}(M(t) - (2\log t)^{1/2})}{\log\log t} = \frac{1}{\alpha} + \frac{1}{2} \quad \text{a.s.}$$

$$\lim_{t \to \infty} inf \frac{(2\log t)^{1/2}(M(t) - (2\log t)^{1/2})}{\log\log t} = \frac{1}{\alpha} - \frac{1}{2} \quad \text{a.s.}$$

These results may be extended to non-stationary case. (i. e. correlation function is $r(s,t) = 1 - |s-t|^\alpha H(|s-t|) + o(|s-t|^\alpha H(|s-t|)),\ (|s-t| \longrightarrow \infty)$

*author is a visitor

Symposium on Applied Probability
IMS/Sheffield August 1989
List of Participants

ABAKUKS A
BIRBECK COLL
MALET STREET
LONDON WC1E 7HX

ADLER A
DEPT OF MATH
ILLINOIS INST OF TECH
CHICAGO
IL 60616
USA

AL-GRAIAN M
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

ALDOUS D
STATISTICS DEPT
U.C. BERKELEY
CA 94720
USA

AMARAL-TURKMAN M A
BLOCO C2 CAMPO GRANDE
CIDADE UNIVERSITARIA
1700 LISBOA
PORTUGAL

ANDERSON C W
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

ANYUE C
RM 4607 JCMB
DEPT OF STATISTICS
UNIVERSITY OF EDINBURGH
EDINBURGH EH9 3JZ

ARJAS E
DEPT OF APP MATH AND STATS
OULU UNIVERSITY
OULU 90570
FINLAND

ARZBERGER P
NATIONAL SCIENCE FOUNDATION
1800 G ST N W
ROOM 339
WASHINGTON DC 20550
USA

ATHREYA K B
DEPT OF STATS
SNEDECOR HALL
IOWA STATE UNIV
AMES
IOWA 50011
USA

BAILEY B J R
FACULTY OF MATHEMATICAL STUDIES
THE UNIVERSITY
SOUTHAMPTON SO9 5NH

BALDING D
DEPT STATISTICS
1 SOUTH PARKS ROAD
OXFORD OX1 3TG

BALL F
DEPT MATHEMATICS
UNIVERSITY OF NOTTINGHAM
NOTTINGHAM NG7 2RD

BARBOUR A D
INST. ANGEWANDTE MATH
RAMISTRASSE 74
CH-8001 ZURICH
SWITZERLAND

BARNETT V
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

BASAWA I
DEPT OF STATISTICS
UNIVERSITY OF GEORGIA
ATHENS
GEORGIA 30602
USA

BATHER J A
MATHEMATICS DIVISION
UNIV OF SUSSEX
FALMER
BRIGHTON BN1 9QH

BEBBINGTON M
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

BECKER N G
STATISTICAL RESEARCH UNIT
3 BLEGDAMSVEJ
COPENHAGEN N
DK-2200
DENMARK

BENKHEROUF L
SCHOOL OF MANAGEMENT
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

BIGGINS J D
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

BINGHAM M S
49 CHANTRY WAY EAST
SWANLAND
Nth FERRIBY
HULL HU14 30F

BINGHAM N H
DEPT OF MATHS
ROYAL HOLLOWAY AND BEDFORD NEW COLLEGE
EGHAM HILL
EGHAM
SURREY TW20 0EX

BISHOP D T
ICRF
3K SPRINGFIELD HOUSE
HYDE TERRACE
LEEDS LS2 9LU

BLACKWELL P
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

BOLTHAUSEN E
TECHNISCHE UNIVERSITAET
FACHBEREICH MATHEMATIK
STRASSE DES 17 JUNI 136
D1 BERLIN 12
W GERMANY

BOSE A
DEPT OF MATH AND STATS
CARLETON UNIV
OTTAWA
ONTARIO K1S 5B6
CANADA

BRANSON D
DEPT OF MATHEMATICS
WIVENHOE PARK
UNIV OF ESSEX
COLCHESTER
ESSEX CO4 3SQ

BUHLER W
MENZELSTR 14
D-65 MAINZ 31
FEDERAL REP GERMANY

BUNGE J
PO BOX 1902
GAMBIER
OHIO 43022
USA

CAIRNS J G
DEPT ACTUARIAL MATH AND STATS
HERIOT-WATT UNIV
RICCARTON
EDINBURGH EH14 4AS

CANNINGS C
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

CHAGANTY N R
DEPT OF MATHEMATICS AND STATISTICS
OLD DOMINION UNIV. NORFOLK
VIRGINIA
23529-0077
U.S.A.

CHAN T
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

CHAUVIN B
LAB DE PROBABILITES UNIV PARIS VI
TOUR 56-4 PLACE JUSSIEU
PARIS 75252
FRANCE

COLEMAN R
DEPT OF MATHEMATICS
IMPERIAL COLLEGE
HUXLEY BUILDING
180 QUEEN'S GATE
LONDON SW7 2BZ

COLES S
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

COLLINS E J
SCHOOL OF MATHS
UNIVERSITY WALK
BRISTOL BS8 1TW

COPE G A
BRITISH TELECOM RESEARCH LABS
MARTLESHAM HEATH
IPSWICH IP5 7RE

D'SOUZA J
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

DALY F
FACULTY OF MATHEMATICS
THE OPEN UNIVERSITY
MILTON KEYNES MK7 6AA

DANIELS H
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

DARLING R W R
MATH DEPT
UNIVERSITY OF SOUTH FLORIDA
TAMPA
FLORIDA 33620-5700
USA

DAVIS M H A
DEPT OF ELEC ENG
IMPERIAL COLLEGE
LONDON SW7 2BT

DEHLING H
DEPT OF MATHEMATICS
UNIV OF GRONINGEN
PO BOX 800
9700AV GRONINGEN
THE NETHERLANDS

DEVROYE L
SCHOOL OF COMPUTER SCIENCE
MCGILL UNIVERSITY
805 SHERBROOKE ST WEST
MONTREAL H3A 2K6
CANADA

DIETZ K
WESTBAHNHOF STR 55
D7400 TUBINGEN
FED REP GERMANY

DINGES H
FB MATHEMATIK
UNIV FRANKFURT
FRANKFURT/M 6000
FED REP GERMANY

DONNELLY P
SCHOOL OF MATHEMATICAL SCIENCES
QUEEN MARY COLLEGE
MILE END ROAD
LONDON E1 4NS

DUFFIE D
GRADUATE SCHOOL OF BUSINESS
STANFORD UNIV
STANFORD
CA 94305-5015
USA

DURR D
MATHEMATISCHES INSTITUT DER UNIVERSITAT MUNCHEN
THERESIENSTRASSE 39
D-8000 MUNCHEN 2
FED REP GERMANY

DURRETT R
DEPT OF MATH
WHITE HALL
CORNELL UNIV
ITHACA
NY 14850
USA

ETHIER S
DEPT OF MATH
UNIV OF UTAH
SALT LAKE CITY
UT 84112
USA

FIELLER N R J
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

FLENLEY E C
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

FOSAM E B
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

GANI J
DEPT STATISTICS AND APPLIED PROBABILITY
SANTA BARBARA
CALIFORNIA 93106
USA

GODBOLE A
MATHEMATICAL SCIENCES DEPT
M T U
HOUGHTON
MICHIGAN 49931
USA

GREEN J R
125 BROWNMOOR LANE
CROSBY
LIVERPOOL
L23 9SF

GREENWOOD P
DEPT OF MATHS
UNIV OF BRITISH COLUMBIA
VANCOUVER BC V6T 1Y4
CANADA

GREY D R
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

GRIFFITHS R
MATHEMATICS DEPT
MONASH UNIV
CLAYTON
VIC 3168
AUSTRALIA

GUT A
UPPSALA UNIVERSITY
DEPT OF MATHEMATICS
THUNBERGSRAGEN 3
UPPSALA S-75238
SWEDEN

de HAAN L
ERASMUS UNIVERSITY
PO BOX 1738
ROTTERDAM 3000 DR
THE NETHERLANDS

HAGWOOD R
NAT INST STANDARDS AND TECHNOLOGY
STATISTICAL ENGINNEERING DIVISION DIV-714
GAITHERSBURG
MARYLAND 20899
USA

HAIGH J
MATHS DIVISION
UNIV OF SUSSEX
FALMER
BRIGHTON BN2 2AA

HAJEK B
UNIV OF ILLINOIS
1101 WEST SPRINGFIELD AV
URBANA
IL 61801-3082
USA

HAMBLY B
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

HANSEN J
MATH DEPT
TUFTS UNI
MEDFORD
MA 02155
USA

HARRISON J M
GRADUATE SCHOOL OF BUISNESS
STANFORD
CA 94305-5015
USA

HEATH D
ORIE
UPSON
CORNELL UNIV
ITHACA
NY 14853
USA

HEYDE C C
DEPT STATISTICS
IAS
AUSTRALIAN NATIONAL UNIVERSITY
GPO BOX 4
CANBERRA ACT2601
AUSTRALIA

HITCHCOCK S E
FACULTY OF MATHEMATICS
OPEN UNIVERSITY
WALTON HALL
MILTON KEYNES MK7 6AA

HITCHCOCK M
APPLIED PROBABILITY OFFICE
DEPT PROB AND STATS
THE UNIVERSITY
SHEFFIELD S3 7RH

HOCHBERG K
DEPT OF MATH AND COMP SCI
BAR-ILAN UNIV
RAMAT-GAN 52900
ISRAEL

HOLST L
DEPT. MATHEMATICS
ROYAL INST. TECHNOLOGY
STOCKHOLM S-10044
SWEDEN

HUANG W-J
INST APPLIED MATHS
NATIONAL SUN YAT-SEN UNIVERSITY
KAOHSIUNG
TAIWAN 80424

HUANG M-N
INST OF APPLIED MATH
NATIONAL SUN YAT-SEN UNIV
KAOHSIUNG
TAIWAN 80424

HUNT P
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

IMHOF J-P
SECTION MATHEMATIQUE
CASE POSTALE 240
1211 GENEVA 24
SWITZERLAND

IOSSIF G E
MATHEMATICS FACULTY
OPEN UNIV
WALTON HALL
MILTON KEYNES MK7 6AA

JAGERS P
DEPT MATHEMATICS
CHALMERS AND GOTHENBURG UNIVERSITIES
GOTHENBURG S-41296
SWEDEN

JALALI A
DEPT OF MANAGEMENT SC AND STATS
UNIV COLLEGE SWANSEA
SWANSEA SA2 8PP

KELLY F P
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

KENDALL W S
STATISTICS DEPT
UNIVERSITY OF WARWICK
COVENTRY CV4 7AL

KENDALL D
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

KENNEDY D P
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

KENNEDY J
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

KERSTING G
ROBERT MAYER STR 10
D-6000 FRANKFURT
FED REP GERMANY

KIPNIS C
UNIV PARIS VII
FRANCE

KOLASSA J
DEPT STATISTICS
5734 S UNIVERSITY AVENUE
CHICAGO
ILLINOIS 60637
USA

KREBS W
DEPT OF STATS
FLORIDA STATE UNIV
TALLAHASSEE
FL 32301
USA

KURTZ T
DEPT MATH
UNIV OF WISCONSIN
MADISON
WI 53706
USA

LAWS N
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

LEE P M
WENTWORTH COLLEGE
UNIVERSITY OF YORK
HESLINGTON
YORK YO1 5DD

LEFEBVRE M
ECOLE POLYTECHNIQUE
C P. 6079
SUCC A
MONTREAL H3C 3A7
CANADA

LEWIS T
39 WALCOT ROAD
DISS
NORFOLK IP22 3DH

LOUTH G M
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

LOYNES R M
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

MACPHEE I M
DEPT OF MATHEMATICS
DURHAM UNIVERSITY
DURHAM DH1 3LE

MANWELL J G
PAISLEY COLLEGE OF TECHNOLOGY
HIGH STREET
PAISLEY PA1 2BE
SCOTLAND

MARTIN-LOF A
DEPT MATH STATISTICS
UNIVERSITY OF STOCKHOLM
BOX 6701
HAGAGATAN 23
S-11385 STOCKHOLM
SWEDEN

MCGILLIVRAY I E
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

MCKENDRICK I J
DEPT ACTUARIAL MATH AND STATS
HERIOT-WATT UNIV
RICCARTON
EDINBURGH EH14 4AS

MIDDLETON R
DEPT OF STATISTICS
1 SOUTH PARKS RD
OXFORD OX1 3TG

MIJNHEER J
DEPT OF MATHEMATICS
UNIVERSITY OF LEIDEN
NIELS BOHRWEG 1
LEIDEN 2333 CA
THE NETHERLANDS

MOLLISON D
DEPT ACTUARIAL MATH AND STATS
HERIOT-WATT UNIV
RICCARTON
EDINBURGH EH14 4AS

MORTIMER T
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

NGUYEN B
DEPT OF MATH
IIT CENTER
CHICAGO
ILLINOIS 60616
USA

O'BRIEN G L
DEPT OF MATHEMATICS
YORK UNIVERSITY
NORTH YORK
ONTARIO M3J 1P3
CANADA

PATIL S
DEPT OF MATH
TENN TECH UNIVERSITY
COOKEVILLE
TN 38505
USA

PATTERSON R
DEPT OF MATH AND COMP SCI
GEORGIA STATE UNIV
ATLANTA
GEORGIA 30303
USA

PEREIRA H J
BLOCO C2 CAMPO GRANDE
CIDADE UNIVERSITARIA
1700 LISBOA
PORTUGAL

PHELAN M
E422 E'QUAD
PRINCETON UNIVERSITY
PRINCETON
NJ 08540
USA

PITTS S
DEPT OF MATHEMATICS
IMPERIAL COLLEGE
180 QUEENS GATE
LONDON SW7 2BT

PRABHU N U
338 UPSON HALL
ITHACA
NEWYORK 14853
USA

PREATER J
MATHS DEPT
UNIV OF KEELE
KEELE ST5 5BG

PYKE R
DEPT OF MATH GN-50
UNIV OF WASHINGTON
SEATTLE
WA 98195
USA

QUINE M.
UNIVERSITY OF SYDNEY
DEPT OF MATHEMATICAL STATISTICS
NSW 2006
AUSTRALIA

RENSHAW E
DEPT OF STATISTICS
J C M B
KING'S BUILDING
MAYFIELD ROAD
EDINBURGH EH9 3JZ

ROBERTS G
DEPT OF MATHS
UNIV OF NOTTINGHAM
NOTTINGHAM NG7 2RD

ROGERS L C G
STATISTICAL LABORATORY
16 MILL LANE
CAMBRIDGE CB2 1SB

SAWYER S
DEPT OF MATHEMATICS
WASHINGTON UNIVERSITY
ST LOUIS
MISSOURI 63130
USA

SHREVE S
DEPT OF MATH
CARNEGIE MELLON UNIV
PITTSBURGH
PA 15213
USA

SMITH R L
DEPT OF MATHEMATICS
UNIV OF SURREY
GUILDFORD GU2 5XH

SMITH P A
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

STANFORD E
DEPT OF STATISTICAL AND ACTUARIAL SCI
U W O
LONDON
ONTARIO N6A 5B9
CANADA

STEELE M
E-QUAD E-220
OLDEN STREET
PRINCETON
NJ 08545
USA

TANG S Y
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

TAVARE S.
MATH DEPT
UNIV OF UTAH
SALT LAKE CITY
UT 84112
USA

TAWN J
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

TAYLOR R L
DEPT OF STATISTICS
UNIVERSITY OF GEORGIA
ATHENS
GEORGIA 30602
USA

TURKMAN K F
BLOCO C2 CAMPO GRANDE
CIDADE UNIVERSITARIA
1700 LISBOA
PORTUGAL

VILAPLANA J P
PO BOX 32
E-48940 LEJONA
SPAIN

WEISSMAN I
FACULTY OF INDUSTRIAL ENGINEERING
TECHNION - ISRAEL INST OF TECH
HAIFA 32000
ISRAEL

WHITTLE P
DEPT PURE MATHS AND MATH STATS
STATISTICAL LAB
16 MILL LANE
CAMBRIDGE CB2 1SB

WILLIAMSON P
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

WONG E
FLAT 3
52 PRINCES GATE
LONDON SW7 2PG

WRIGHT C
DEPT OF STATISTICS
LEEDS UNIV
LEEDS LS2 9JT

ZACHARY S
HERIOT-WATT UNIV
DEPT OF ACTUARIAL MATHS AND STATS
RICCARTON
EDINBURGH EH14 4AS

ZHUNWEI L
DEPT OF PROB AND STATS
SHEFFIELD UNIVERSITY
SHEFFIELD S3 7RH

ZIEDINS I
HERIOT-WATT UNIV
DEPT OF ACTUARIAL MATHS AND STATS
RICCARTON
EDINBURGH EH14 4AS